High-p_T π^0 suppression in Au+Au collisions at $\sqrt{s_{_{NN}}} = 200$ GeV.

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Neutral pions with p_T = 1 - 8 GeV/c have been measured for 9 centrality classes in Au+Au collisions at $\sqrt{s_{_{NN}}}$ = 200 GeV by the PHENIX experiment at RHIC. The π^0 multiplicity in central reactions is significantly below the binary collision scaled yields from both peripheral Au+Au and pp reactions. The observed suppression sets in for the 50-70% centrality class and increases with p_T and centrality. For the most central bin, the deficit amounts to a factor ∼2.5 at $p_T \sim 2$ GeV/c gradually increasing to a factor ∼6 at $p_T \sim 8$ GeV/c.

1. Introduction

One of the primary goals of the PHENIX experiment at BNL RHIC is the measurement of hadron spectra out to large transverse momentum (p_T) in high-energy heavy-ion (HI) collisions. High-p_T particles result from the fragmentation of quarks and gluons produced in large Q^2 parton-parton scattering processes during the earliest stages of a HI collision and provide direct signatures of the partonic phase of the reaction. Interestingly, hard scattering multiplicities can be quantitatively compared (after scaling with the number of binary nucleon-nucleon, NN, inelastic collisions N_{coll}) to: (i) baseline "vacuum" (pp) and "cold medium" (pA) data, and (ii) perturbative QCD predictions. In both cases, any departure (deficit or excess) from the "expected" results provides information on the strongly interacting hot and dense medium created in the reaction. One of the most intriguing results from the first RHIC run was the suppressed yield of moderately high-p_T π^0 ($p_T \approx 1.5$ - 4.0 GeV/c) in central Au+Au collisions at $\sqrt{s_{_{NN}}}$ = 130 GeV with respect to the scaled pp extrapolation [1]. Such a suppression is in qualitative agreement with theoretical predictions of parton energy loss effects ("jet quenching") in an opaque medium, the amount of energy loss being proportional to the reached gluon density [2].

2. Experimental setup and data analysis

During the 2001-2002 RHIC run, the full PHENIX Electromagnetic Calorimeter EMCal was instrumented providing a solid angle coverage of approximately $\Delta\eta = 0.7$ and $\Delta\phi = \pi$. The integrated luminosity of $\sqrt{s_{_{NN}}}$ = 200 GeV Au+Au collisions was about 25 μb^{-1} and the collected neutral pion statistics was a factor of $\sim 10^2$ larger than in Run-1, allowing the exploration of the π^0 spectra up to much larger values in p_T and for finer centrality

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classes. PHENIX also measured the π^0 spectrum in pp collisions at the same $\sqrt{s}$ [3]. The combination of full acceptance, high statistics, and the measurement of pp data in the same detector permits a very precise study of the high-p_T π^0 suppression at 200 GeV.

The data presented in this analysis correspond to pions from $30M$ $AuAu$ "minimum bias" events with vertex position $|z| < 30$ cm. The PHENIX EMCal consists of 4 lead-scintillator (PbSc) sectors (2592 towers per sector with $5.25\times5.25\times37.0$ cm^3 size) in the west central arm plus 2 more sectors in the east one, and 2 lead-glass (PbGl) sectors (4608 towers of $4.0\times4.0\times40.0$ cm^3) in the east arm. The large radial distance of the calorimeter to the interaction region, of $\sim$5 m, keeps the detector occupancy reasonably low (<15%) even in the highest multiplicity events of HI collisions at RHIC. Event centrality is determined by correlating the charge and energy measured in two global detector systems: the Beam-Beam Counters and the Zero Degree Calorimeters. Neutral pions are reconstructed through an invariant mass analysis of γ pairs detected in the 8 active EMCal sectors. The raw π^0 spectra are then corrected for geometric acceptance and (multiplicity-dependent) reconstruction and efficiency losses. The corrections were determined embedding $2M$ simulated π^0 into real events. The final systematic errors in the fully corrected spectra are of the order of $\pm$25%. Two independent analyses were carried out for the PbSc (shown here) and PbGl calorimeters yielding consistent results within the overall systematic error.

3. Results

Figure 1 shows the resulting π^0 p_T distributions measured for 70-80% peripheral (*left*) and for 0-10% central (*right*) $AuAu$ collisions, compared to the π^0 yield measured in pp

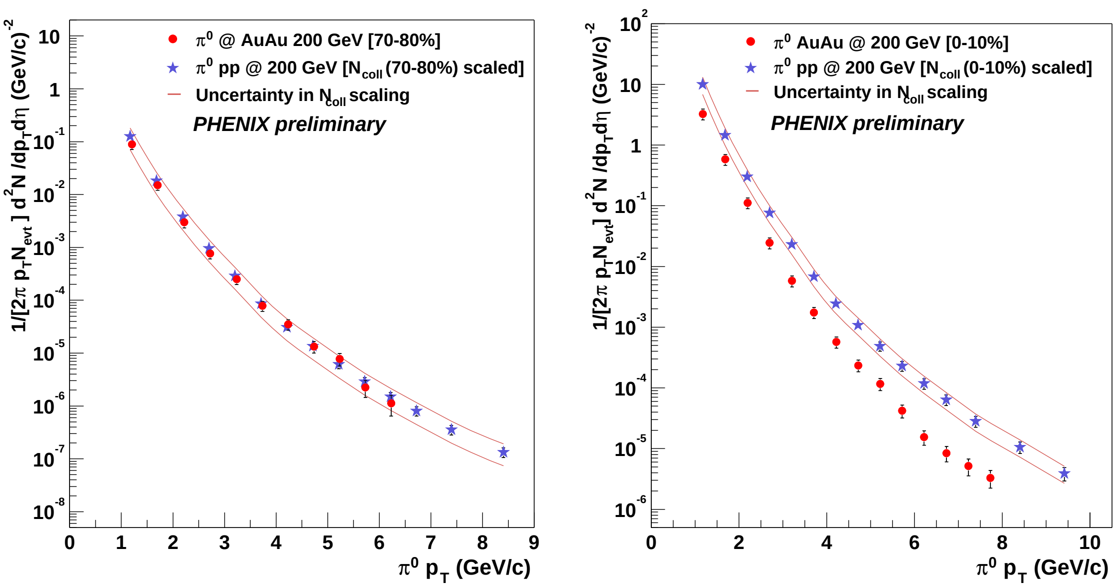

Figure 1. Invariant π^0 yields measured in peripheral (*left*) and in central (*right*) $AuAu$ collisions (*circles*), compared to the N_{coll} scaled pp π^0 yields (*stars*) [3]. The lines indicate the systematic errors in the scaled pp yields due to the uncertainties in N_{coll} and luminosity.

collisions [3] scaled by the corresponding number of binary collisions given by a Glauber model calculation: $N_{coll}(70-80\%) = 12.3 \pm 4.0$, and $N_{coll}(0-10\%) = 975 \pm 94$ respectively. Whereas π^0 production in peripheral reactions is consistent with the point-like scaling expectation, the spectrum from the most central reactions is clearly suppressed (by a factor ~2.5 at $p_T \sim 2$ GeV/c increasing up to a factor ~6 at $p_T \sim 8$ GeV/c). A complementary way to depict such a suppression is using the *nuclear modification factor*

$$R_{AA}(p_T) \;=\; \frac{d^2N^{\pi^0}_{AA}/d\eta dp_T}{\langle N_{coll}\rangle\, d^2N^{\pi^0}_{pp}/d\eta dp_T}, \tag{1}$$

which quantifies the deviation of the π^0 yield in AA collisions with respect to the pp behaviour (i.e. with respect to the absence of nuclear-medium effects) in terms of suppression or enhancement (R_{AA} smaller or larger than unity, respectively). Figure 2a shows the p_T dependence of R_{AA} for π^0 emitted in 0-10% central $AuAu$ reactions at two center-of-mass energies: 200 GeV (*circles*) and 130 GeV [1] (*stars*). Three interesting conclusions can be extracted from this plot above[3] $p_T = 2$ GeV/c:

1. The R_{AA} values at 200 GeV and 130 GeV are compatible (within their corresponding systematic errors) and clearly below unity: $R_{AA}(2\text{ GeV/c}) \sim 0.4$ gradually decreasing down to $R_{AA}(8\text{ GeV/c}) \sim 0.16$ for the highest $\sqrt{s}$.

2. The low R_{AA} values measured at RHIC are clearly at variance with the high-p_T hadron production enhancement ($R_{AA} >1$) observed at CERN-SPS energies (WA98 data) [4, 5]: No "Cronin effect" [6] is observed.

3. The trend of R_{AA} below unity in the range $p_T = 2-8$ GeV/c (corresponding to parton fractional momenta $x = 2p_T/\sqrt{s} \sim 0.02-0.1$) seems to be inconsistent with initial-state nuclear effects ("shadowing" of the Au parton distribution function). Indeed, shadowing is known [7] to decrease for larger x (turning into "anti-shadowing" above $x \sim 0.1$), whereas R_{AA} consistently diminishes for larger p_T values.

The same quenching is evident in the nuclear modification factor constructed not from the ratio of $AuAu$ to pp pions but from the ratio of central to peripheral $AuAu$ π^0 spectra (scaled by their corresponding centrality-dependent N_{coll}). Such R_{AA} (see fig. 5 of S. Mioduszewski contribution [5]), -which have part of the systematic errors on the spectra cancelled out-, are also well below one in central collisions. Finally, fig. 2b shows the evolution of the π^0 suppression at three fixed p_T bins (p_T= 2.2, 4.2 and 6.2 GeV/c) as a function of the reaction centrality. The transition from the binary-scaling behaviour apparent in the peripheral region ($R_{AA} \sim 1$, centrality class > 70%) to the highly suppressed central region is gradual and seems to occur over the 50-70% centrality bin (the systematic uncertainty in R_{AA}, not shown in this plot, is of the order of ~20%).

[3]For $p_T < 2$ GeV/c, R_{AA} is below unity in all cases since the bulk of particle production is due to soft processes which scale with the number of participant nucleons (N_{part}) rather than with N_{coll}.

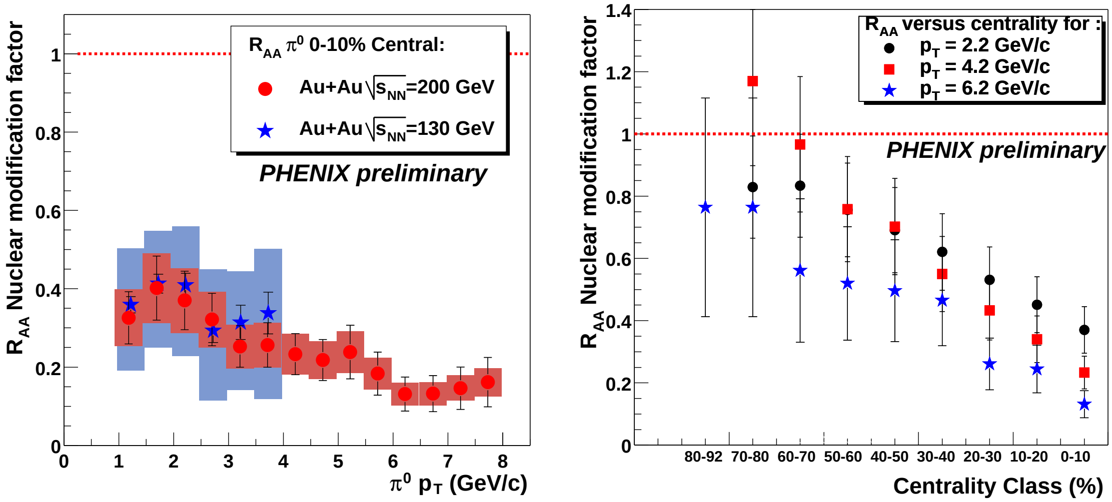

Figure 2. *Left*: Nuclear modification factor for π^0 emitted in top 10% central $AuAu$ collisions at 200 GeV (*circles*), and 130 GeV (*stars*) (the bands show the syst. uncertainties). *Right*: R_{AA} at 200 GeV as a function of the reaction centrality for 3 fixed p_T bins.

4. Conclusions

Transverse momentum spectra of neutral pions have been measured at mid-rapidity by the PHENIX EMCal up to $p_T = 8$ GeV/c for 9 different centrality classes from $30M$ Au+Au "minimum bias" events at $\sqrt{s_{NN}} = 200$ GeV. The spectral shape and invariant yield of peripheral reactions are consistent with that of *pp* collisions scaled by the number of inelastic NN collisions. Central yields, on the other hand, are significantly lower than peripheral $AuAu$ and *pp* binary-scaled extrapolations, in agreement with the results found at $\sqrt{s_{NN}} = 130$ GeV. The observed quenching sets in over the 50-70% centrality class and increases with p_T and centrality, being as high as a factor 6 at $p_T = 8$ GeV/c in the top 10% central collisions. For these collisions, the nuclear modification factor R_{AA} is systematically well below one and decreases gradually with p_T, at variance with the common initial-state "phenomenology": (i) no "Cronin enhancement" is observed, and (ii) the growing suppression with p_T seems inconsistent with the decreasing dependence of "shadowing" on x. Since initial-state nuclear effects seem not determinant, final-state medium effects appear as a promising explanation for the observed high-p_T pion deficit.

REFERENCES

1. K. Adcox *et al.* [PHENIX Collaboration], Phys. Rev. Lett. 88 (2002) 022301.
2. I. Sarcevic *et al.*, I. Vitev *et al.*, and P. Levai *et al.*, these Proceedings.
3. H. Torii [PHENIX Collaboration], these Proceedings.
4. K. Reygers [WA98 Collaboration], nucl-ex/0202018.
5. S. Mioduszewski [PHENIX Collaboration], these Proceedings.
6. D. Antreasyan *et al.*, Phys. Rev. D19 (1979) 764.
7. K. Eskola *et al.*, Phys. Lett. B532 (2002) 222.